

COMUNICACIÓN DE TRABAJO – CONTRIBUTED PAPER

**The Role of Exploding QSOs in Explosive Models
 of Evolution, Formation and End of Galaxies**

S. Lipari¹, M. Bergmann², S. F. Sanchez³, R. Terlevich⁴, E. Mediavilla⁵, B. Punsly, B. Garcia⁵, W. Zheng⁶, Y. Taniguchi⁷, R. Sistero¹
¹*Observatorio Astronomico de Cordoba and CONICET*; ²*Gemini Observatory, Chile*; ³*Calar Alto Observatory, Spain*; ⁴*Univ. of Cambridge, UK*; ⁵*Inst. de Astrofísica de Canarias, Spain*; ⁶*Johns Hopkins Univ., USA*; ⁷*Tohoku Univ., Japan*

Resumen. In this work we analyse the role and evidence of exploding BAL + IR + Fe II QSOs, and their relation with new –and previous– explosive models for evolution, formation and end of galaxies.

1. Evolution of Galaxies/QSOs and the Role of Extreme Out Flow/BAL

Main current issues in astrophysics (from the theoretical and observational point of view) are the study of *the evolution of IR mergers, IR/BAL QSOs, extreme star formation processes and the relations between them*. These issues play an important role in practically every scenario of formation and evolution of galaxies and active galactic nuclei (AGNs) (see for references Lipari & Terlevich 2006; Sanders & Mirabel 1996).

On the other hand, there is increase evidence that extreme galactic out flow (OF) and BAL systems play a main role at very high redshift ($Z > 5.0$), i.e. the young universe (Frye, Broadhurst, Benitez 2002; Maiolino et al. 2003, 2004a,c; Lipari 1994; Lipari et al. 2005, 2006a,b, 2007; Lipari & Terlevich 2006). At low redshift, there are strong evidence of extreme OF, mainly associated with extreme starburst in IR galaxies (like M 82, Arp 220, NGC 5514, NGC 3256, NGC 2623; see for references Heckman et al. 1987, 1990; Lipari et al. 2004a,b,c).

The IRAS colour-colour diagrams have been used as an important tool to detect and discriminate different types of activity in the nuclear/circumnuclear regions of galaxies. Thus, this tool is also important for the study of possible links between different phase of galaxy and QSO evolution. Specifically, Lipari (1994) found that the IR colours (i.e., IR energy distribution) of ~ 10 extreme IR + Fe II QSOs are distributed between the power law (PL) and the black-body (BB) regions: i.e., the *transition area*. It is important to remark that of a total of ~ 10 IR transition objects of this original sample, the first 4 systems are BAL IR QSOs. Therefore, we already suggested that BALs IR QSOs (like Mrk 231, IRAS 07598+6508, IRAS 17002+5153 and IRAS 14026+4341) could be associated with the *young phase of the QSO activity/evolution (and the link between IR mergers and standard QSOs)*.

Very recently, using our data base of more than 50 IR Mergers and QSOs with galactic winds and using for comparison the large sample of standard PG QSO (from Boroson & Green 1992) we have expanded our previous study. Lipari et

al. (2005; in their Fig. 15) show the IR energy distribution [spectral indexes: $\alpha(60, 25)$ vs. $\alpha(100, 60)$] for IR mergers and IR QSO with GW (originally 51 IR systems). An inspection of this diagram clearly shows the following: (i) All the IR mergers with low velocity OF (LVOF) are located very close to the BB and starburst area. (ii) Almost all the IR QSOs with extreme velocity OF (EVOF) are located in the transition region. (iii) The standard QSOs and radio QSOs are located around the PL region. (iv) All the BAL IR QSOs are located in the transition region, in almost a clear sequence: from Mrk 231 (close to the BB area) \rightarrow IRAS 07598+6508 \rightarrow IRAS04505-2958 \rightarrow IRAS 21219-1757 \rightarrow IRAS/PG 17072+5153 and IRAS 14026+4341 (close to the PL area) \rightarrow standard QSOs. These results first confirm our previous finding (obtained from a small sample of IR galaxies): in the sense that *IR QSOs are probably young, composite and transition objects* (between IR mergers and standard QSOs). Furthermore, in this IR colours diagram a main evolutionary parameter is the values of the Out Flow: from IR mergers with Low Velocity OFs to IR QSOs with Extreme Velocity OFs.

2. Explosive Models for Formation and Evolution of Galaxies/QSOs

The presence of *extreme explosions, OF and galactic-winds* –associated mostly to extreme/massive star formation processes– is an important component for different theoretical models of galaxy and QSO formation and evolution. More specifically, 3 main explosive models were already proposed:

1. Ikeuchi (1981) suggested that QSOs were formed and they exploded mainly at the cosmological redshift $Z > 4$. The shock waves propagate through the gaseous medium generated cooled shells (at the shock fronts). Which are split into galaxies of mass of $10^{10-11} M_{\odot}$.
2. Ostriker & Cowie (1981) have proposed a galaxy formation picture in which (after redshift 100) small seed perturbation are supposed to collapse, giving rise to a explosive release of energy from the deaths of the first generation of stars (Pop. III). This energy drives a blast wave into the surrounding gas. Thereby sweeping up a shell of shocked material, which eventually cools. These cool shells are split into galaxies
3. Berman & Suchkov (1991) proposed a hot/explosive model for galaxy formation. They suggest that the period of major star formation of protogalaxy (or even giant galaxies) is preceded by an evolutionary phase of a strong galactic wind. Which is driven by the initial burst of star formation that enriches the protogalaxy with metals. Thus this process revert from contraction to expansion. Specifically, the result of this process is the ejection of enriched material from the outer part of the protogalaxy, while the inner part, after a delay of few Gyr, finally contract and cools down to form the galactic major stellar component.

From the observational point of view, the presence of multiple concentric expanding supergiant bubbles/shells in young composite BAL + IR + Fe II QSOs, with centre in the nucleus and with highly symmetric circular shape could be associated mainly with giant symmetric explosive events (Lipari et 2003, al. 2005,

2006a,b, 2007). In addition, an explosive scenario for the origin of some BAL systems (e.g., in Mrk 231) could explain the SN shape of some BAL light curve variability (Lípari et al. 2005, 2006a,b). These giant explosive events could be explained in a composite scenario/model: where mainly the interaction between the starburst and the AGN could generate giant explosive events. In particular, Artymowicz, Lin, & Wampler (1993) and Collin & Zahn (1999) already analysed the evolution of the star formation (SF) close to super massive black hole (SMBH) and inside of accretion disks. They suggested that the condition of the SF close to the AGNs could be similar to those of the early/first SF events, where giant explosive processes are expected, generated by hypernovae (with very massive progenitors: $M \sim 100\text{--}200 M_{\odot}$; see Heger & Woosley 2002). In accretion disk, the star-gas interactions can lead to a special mode of massive star formation, leading to very powerful SN or hypernova explosions.

In order to understand giant explosive outbursts (i.e., from hypernova, population III of stars, etc), it is required more detailed theoretical and observational studies. Very recently, the discovery of the most luminous SN 2006GY (in NGC 1260, Smith et al. 2006) powered by the death of extremely massive star (like Eta Carinae) and with Type IIn SN properties, strongly support the existence of extreme explosive events associated with very massive stars.

3. Role/Evidence of Explosive QSOs and a New Explosive Model for Formation and End of Galaxies

New Gemini/GMOS 3D spectroscopic data of young, composite and transition BAL + IR + Fe II QSOs: Mrk 231, IRAS 04505-2958, IRAS/PG 17072+5153, IRAS 07598+6508, IRAS 14026+4341 and IRAS 21219-1757 (Lipari et al. 2006a,b, 2007) strongly support the reality of these giant explosive processes.

3.1. The BAL + IR + Fe II QSO: Mrk 231

Using high resolution HST and La Palma/NOT images we detected –for Mrk 231– 4 nuclear expanding superbubbles with radius $r \sim 2.9, 1.5, 1.0$, and 0.6 kpc, plus a starburst toroid at $r \sim 0.2$ kpc (Lipari et al. 2005, 2006a, 1994). For these bubbles, Gemini/GMOS and La Palma/Integral 3D data ($H\alpha$ velocity field map and 3D spectra) show in the 4 more external bubbles, multiple emission line components with low and high OF velocities, of $\langle V_{OF} \rangle$ low Vel. = $[-(100, 400) \pm 30]$, and high Vel. $[-(800, 1000) \pm 30] \text{ km s}^{-1}$. We suggest that these giant bubbles are associated with the large scale nuclear OF component, which is generated –at least in part– by the extreme nuclear starburst: with giant-SN/hypernova explosions.

In addition, we also found for Mark 231 that the BAL I system could be associated with bipolar outflow generated by the weak/sub-relativistic jet; and the BAL III system with a supergiant explosive events (Lípari et al. 2005; Punsly & Lípari 2005). The variability of the short lived BAL-III Na ID system was studied, covering almost all the period in which this system appeared (between $\sim 1984\text{--}2004$). We found that the BAL-III light curve (LC) is very similar to the shape of a SN LC. Therefore the origin of this BAL-III system was discussed, mainly in the frame work of an extreme explosive event.

3.2. The BAL + IR + Fe II QSO: IRAS 04505-2958

Lipari et al. (2005) proposed a *composite hyper-wind scenario* in order to explain the very extended blob/shell (of 30 kpc) found in the new BAL QSO IRAS04505-2958 (this BAL IR-QSO was discovered using the IR colour-colour diagram: Fig. 15 in Lipari et al. 2005). In particular, we have performed a detailed study of HST images and Gemini GMOS-IFU spectroscopic data of IRAS 04505-2958 (see Lipari et al. 2005, 2007; Lipari & Terlevich 2006; see also Magain et al. 2005). In general, we found that IRAS 04505-2958 and Mrk 231 show very similar OF process and properties. Even both QSOs have relatively narrow-or nini/associated-BALs (Lipari et al. 2005, 2006a). They suggested that extreme explosions and extreme starbursts are associated mainly with the interaction between: the QSO and the nuclear star formation process.

More specifically, we have studied in detail the out flow (OF) process and their associated structures, mainly at two large galactic scales: (1) two blobs at radius $r \sim 0.2$ and $0.4''$ (~ 1.1 and 2.2 kpc); and (2) an external super/hypergiant symmetric shell at $r \sim 2.0''$ (11 kpc). In addition, the presence of a very extended hypergiant shells at $r \sim 15''$ (~ 80 kpc) was analysed. From the study of the Gemini data the following main results were obtained: (i) In general the GMOS data show strong emission lines, in almost all the observed GMOS field: $\sim 20 \times 30$ kpc ($\sim 3.5'' \times 5.0''$). Furthermore, multiple emission line systems were detected, in the regions of the shells (which are aligned at $PA \sim 310$: i.e. suggesting a bipolar outflow). These shells also show emission lines ratios consistent with an extreme outflow process and the associated shocks. (ii) For the two more internal blobs (at $r \sim 1$ and 2 kpc) the GMOS data show that these structures are symmetric shells in expansion, with *very similar* properties to those detected recently in the supershells of Mrk 231. In particular, a strong blue continuum component was observed in the region of the galactic wind associated with these 2 shells. (iii) For the external supergiant shell at $2.0''$ (11 kpc) all the kinematics GMOS maps of the ionized gas ([O II], [Ne III], [O III], $H\beta$, $H\alpha$) show continuity in velocities between the QSO and this external shell. The GMOS data suggest that this shell is forming a satellite/companion galaxy. (iv) Using the optical GMOS and HST data plus the IR observation of IRAS 04505-2958 we have confirmed that the more probable source of ultra-luminous IR energy is the QSO.

Therefore, we found that these new GMOS data are in good agreement with our extreme OF + explosive scenario: where part of the ISM of the host galaxy was ejected in the form of multiple shells (which could generate satellite galaxies). This extreme OF process detected in IRAS 04505-2958 could be also associated with 3 main processes or steps in the evolution of QSOs and their host galaxies; specifically: (i) to stop the accretion process in SMBHs/QSOs; (ii) the formation of satellite/companion galaxies by giant explosions; and (iii) to define the final mass of the host galaxy, and even if the explosive nuclear outflow is extremely energetic, this process could disrupt an important fraction (or even all) of the host galaxy. Thus this type of giant QSOs explosions is an interesting process in order to consider as the base for a new model of satellite galaxy formation and (a first) model of galaxy end.

Referencias

- Artymowicz, P., Lin, D., Wampler, E. 1993, ApJ, 409, 592
Berman, V.G., Suchkov, A. 1991, Ap&SS, 184, 169
Boroson, T., Green, R. 1992, ApJS, 80, 109
Collin, S., Zahan, J. 1999, A&A, 344, 433
Frye, B., Broadhurst, T., Benitez, N. 2002, ApJ, 568, 558
Heckman, T., Armus, L., Miley, G. 1987, AJ, 93, 276
Heckman, T., Armus, L., Miley, G. 1990, ApJS, 74, 833
Heger, A., Woosley, S. 2002, ApJ, 567, 532
Ikeuchi, S. 1981, PASJ, 33, 211
Lipari, S. 1994, ApJ, 436, 102
Lipari, S. et al. 1994, ApJ, 427, 174
Lipari, S. et al. 2003, MNRAS, 340, 289
Lipari, S. et al. 2004a, MNRAS, 348, 369
Lipari, S. et al. 2004b, MNRAS, 354, L1
Lipari, S. et al. 2004c, MNRAS, 355, 641
Lipari, S. et al. 2005, MNRAS, 360, 416
Lipari, S. et al. 2006a, MNRAS, submitted, (astrp-ph 0607054)
Lipari, S. et al. 2006b, Bol.AAA, No. 49, in press
Lipari, S. et al. 2007, MNRAS, in preparation,
Lipari, S., Terlevich, R. 2006, MNRAS, 368, 1001
Magain, P. et al. 2005, Nat., 437, 381
Maiolino, R. et al. 2003, ApJ, 596, L155
Maiolino, R. et al. 2004, A&A, 420, 889
Ostriker, B., Cowie, . 1981, ApJ, 243, L127
Punsly, B., Lipari, S. 2005, ApJ, 623, L101
Sanders, D., Mirabel, F. 1996, ARA&A, 34, 789
Smith, N. et al. 2006, ApJ, submitted, (astrp-ph 0612617)